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EVACUATION STUDIES ON AN OFFICE IN A COMMUNITY BUILDING

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ABSTRACT

Office evacuation of a community building was simulated numerically. The occupancy loading was varied with reference to the maximum allowed value in the code. From the simulation results, it is observed that waiting time is a key part in the total evacuation time under crowded conditions. Fire safety management should be worked out to reduce the waiting time. In addition, the requirement of evacuating in 300 s as specified in the code might not be met under high occupant loadings.

1. INTRODUCTION

The fire codes in Hong Kong are basically prescriptive [e.g. 1,2] following those developed decades ago in the UK [e.g. 3] with some slight modifications. Approval of fire safety designs and inspection of the buildings upon completion are held responsible by two government departments. The building design shall be submitted to the Buildings Department BD to check against all fire aspects for approval. Active fire protection systems (or fire service installations) are monitored [4] by the Fire Services Department FSD. There is no Engineering Performance-Based Fire Code (EPBFC) yet. But for those buildings having difficulties in complying with the prescriptive fire safety codes, fire engineering approach FEA on passive construction [5-7] will be accepted by BD since 1998. FEA is similar to performance-based design (PBD) practicing in elsewhere [8-10]. There, evacuation is understood to be a key element.

Escape routes of a building can be designed based on prescriptive approach or FEA. With prescriptive approach, the designers or architects would follow the guidelines laid down in the codes of practice, practice notes for authorized persons and circular letters. Escape routes for buildings in Hong Kong are based on the Means of Escape (MoE) Code [1]. Prescribed figures are specified for the building designers to determine the maximum occupant density of the building, number of staircases in both sprinklered and non-sprinklered buildings, discharge values, travel distance and staircase width.

As stated in the MoE code [1], the evacuation time for each storey to a protected area (e.g. the staircase leading to the exit) should be within a notional period of 2.5 minutes (150 s) for non-sprinklered buildings; and 5 minutes (300 s) for sprinklered buildings. However, for buildings with special features, the escape route is not designed by following the requirements prescribed in the codes of practice. FEA can be adopted to design the escape route.

Standard design data for escape route are not yet specified under FEA. The probable fire scenarios will be studied by reviewing the features, function of the building and the characteristics of the occupancy. Active fire protection systems or fire service installations will be checked for complying with the existing code of practice. The design population and the proposed means of escape can then be designed. Engineering tools are required and evacuation software is commonly used for studying evacuation pattern. In this paper, evacuation in a community building will be studied numerically to demonstrate how key results can be deduced.

2. GEOMETRY

The office located on the 4^{th} floor of a community building as in Fig. 1 was selected to study the evacuation pattern. The height of each floor is 3 m. There are two staircases: SA of width 0.9 m and SB 1.35 m, all to outside at the ground floor. The geometry of the two staircases are different. The walking distance for occupants in SB is longer than that in SA.

Five scenarios are identified to study the effects of blocking the staircase on the evacuation flow rate. The importance of staircases SA and SB can be evaluated. How evacuation can be improved by fire safety management with appropriate guidance is also investigated. Those five scenarios are:

- Scenario 1: Evacuation through both staircases SA and SB.
- Scenario 2: Evacuation through staircase SA, and SB is closed.
- Scenario 3: Evacuation through staircase SB, and SA is closed.
- Scenario 4: To study the horizontal travel time by taking the office at the ground and staircases are the exits. All conditions are the same as scenario 1.
- Scenario 5: Same as scenario 1 with organized evacuation.

The occupant loading in the community building is taken as the maximum allowed value in the MoE code, i.e. 2 persons/m^2. The total number of occupants is 544 and randomly distributed in the floor as shown in Fig. 2. No occupants are assumed in the toilets.

The software buildingEXODUS [11] is selected as the evacuation simulator. The response times for the occupants are randomly distributed between 0 s and 30 s. Averaged values of the response time are shown in Table 1. Other parameters for the staircases are assumed to be the same as the default values in buildingEXODUS 4.0.

The meaning of organized evacuation is that all the available exits are evenly utilized. Effect due to congestion would be minimized. However, this is only an ideal assumption which is difficult to get even in simulation. Such condition is achieved by repeating the simulations by trial and error.

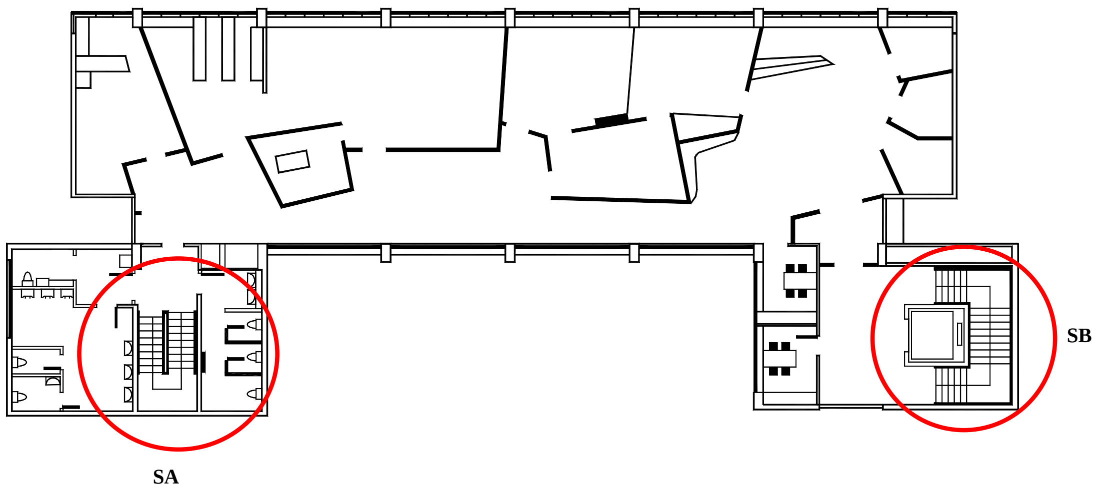


Fig. 1: Geometry layout of the office

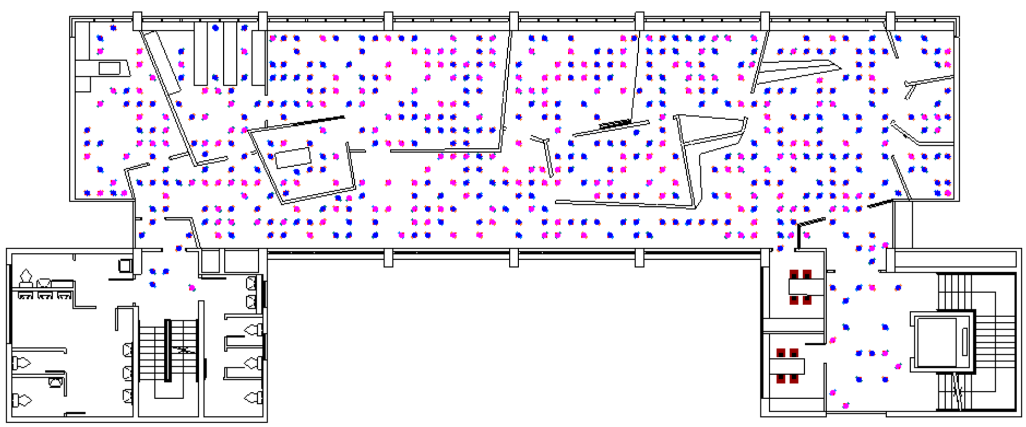


Fig. 2: Assumed distribution of occupants

Table 1: Results for the fire scenarios

Occupancy density / person/m^2	Number of occupants	Scenario	Average response time / s	CWT / s	ATD / m	TET / s
0.11	30	1a	13	1	52	98
		2a	13	7	56	106
		3a	13	2	63	106
		4a	13	1	51	95
0.5	136	1b	15	22	56	152
		2b	15	75	62	259
		3b	15	44	69	207
		4b	15	21	56	144
1.0	272	1c	14	64	59	256
		2c	14	173	65	461
		3c	14	117	73	356
		4c	14	62	59	240
1.5	408	1d	15	109	59	370
		2d	15	278	63	667
		3d	15	184	74	507
		4d	15	107	60	335
2.0	504	1	15	151	58	460
		2	15	378	66	871
		3	15	252	74	650
		4	15	147	59	434
		5	15	147	59	434
2.5	680	1e	14	199	59	584
		2e	14	477	67	1073
		3e	14	324	75	795
		4e	14	189	60	518
3.0	816	1f	15	249	58	716
		2f	15	582	67	1281
		3f	15	406	77	959
		4f	15	238	60	630

3. RESULTS

The results on the cumulative waiting time CWT, average travel distance ATD and total evacuation time TET of the five base scenarios 1, 2, 3, 4 and 5 are shown in Table 1.

The evacuation times required for occupants to evacuate for scenarios 1, 2 and 3 are shown in Fig. 3. It is shown clearly in the figure that using both staircases in scenario 1 would give a much faster evacuation rate than in scenarios 2 and 3 with a staircase blocked. Congestion was observed at 60 s for scenario 1 as in Fig. 4.

In comparing TET for scenarios 1 and 5, good fire safety management would give much faster evacuation with TET reduced from 460 s to 434 s. The reduction appears to be not too significant under the maximum allowed occupant load in the MoE Code.

The travel time along the horizontal direction t_h and time to travel along the vertical direction t_v can be written as:

$$t_h + t_v + CWT = TET \quad (1)$$

By comparing CWT and TET of scenarios 1 and 4, it is shown that t_v is 460 – 151 – (303 – 103) s, i.e. 109 s.

4. EFFECT OF OCCUPANCY DENSITY

Effect of the occupancy density on scenarios 1, 2, 3, and 4 are also studied. The occupancy density varies from 0.11, 0.5, 1.0, 1.5, 2.5 and 3.0 persons/m^2 as shown in Table 1. This gives a total number of occupants as 30, 136, 272, 408, 680 and 816 respectively. The corresponding scenarios are labeled as 1a, 2a, 3a and 4a for 0.11 person/m^2; 2b, 2b, 3b and 4b for 0.5 person/m^2; 1c, 2c, 3c and 4c for 1.0 person/m^2; 1d, 2d, 3d and 4d for 1.5 persons/m^2; 1e, 2e, 3e and 4e for 2.5 persons/m^2; and 1f, 2f, 3f and 4f for 3.0 persons/m^2.

Results on TET are also predicted and plotted in Fig. 5. As observed, the TET increases with the occupancy density. When the occupancy density is increased by about 26 times, the total evacuation time would be increased by 6.6 times with good fire safety management on well-organized evacuation. When the loading is 1.0 person/m^2, it is difficult to meet the requirement of evacuating the office in 300 s, even if the building is sprinklered.

As shown in Fig. 4, congestion is a key point. CWT would be extended to very high values. The ratio of CWT to TET is calculated and plotted in Fig. 6. The value of CWT can be up to 40% of TET.

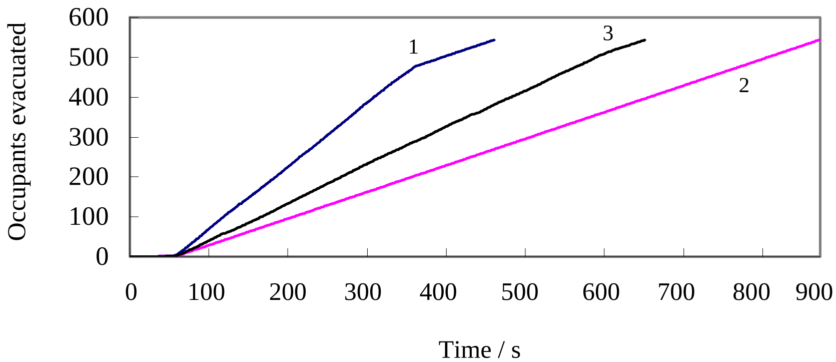
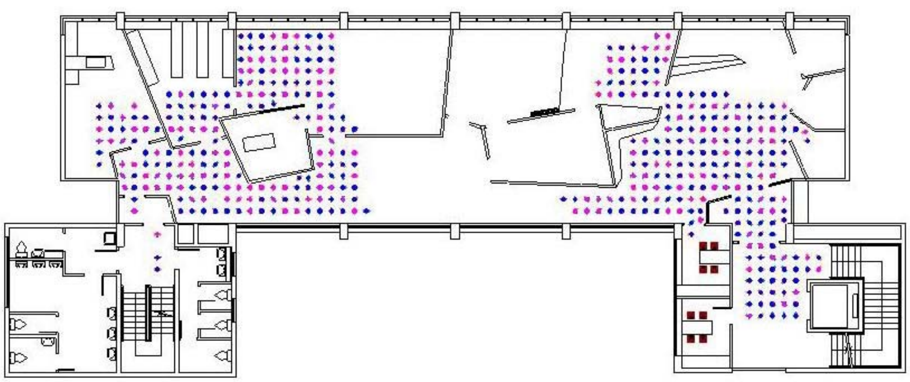
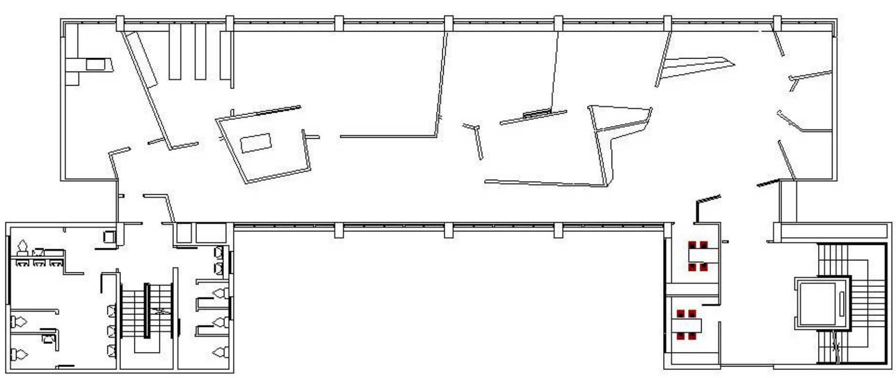


Fig. 3: Evacuation pattern under maximum MoE loading for scenarios 1, 2 and 3

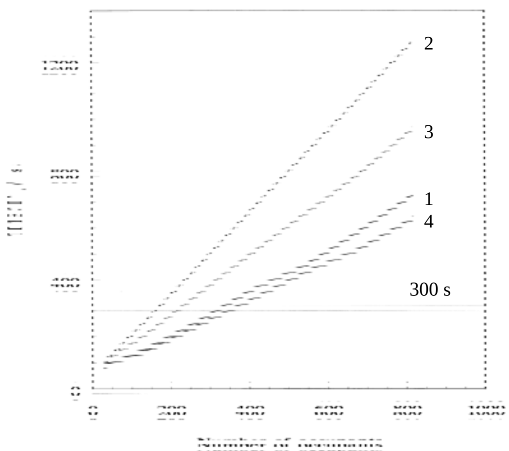


(a) 60 s

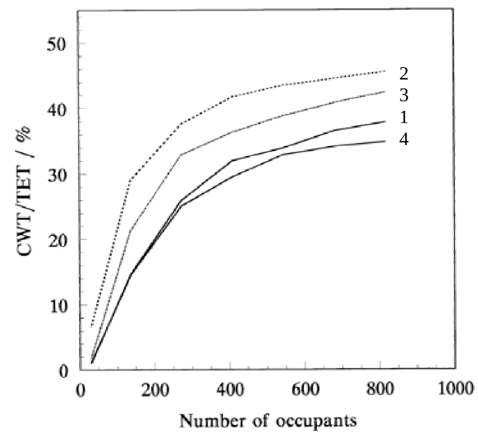


(b) 360 s

Fig. 4: Evacuation for scenario 1



(a) Number of occupants



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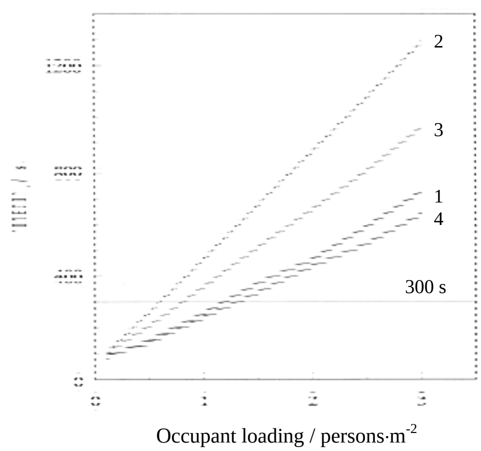
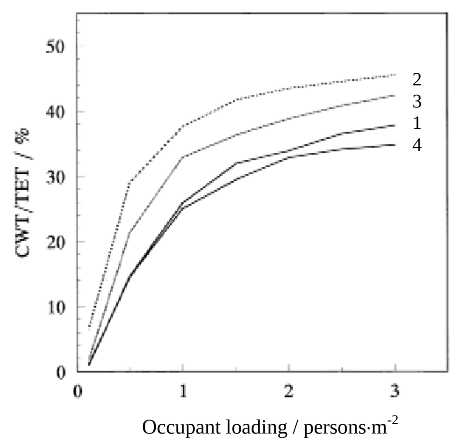


(b) Occupancy loading

Fig. 5: TET under different occupancies



(b) Occupancy loading

Fig. 6: Ratio of CWT to TET

5. CONCLUSION

As demonstrated in the above simulation on evacuation in a community building, the total evacuation time increases with occupancy density. Two points should be noted:

- When the density is low, say below 1.5 persons/m^2, the requirement of evacuating the building in 300 s can be met. No serious congestion was found only at low density. The traveling time is a key component of the total evacuation time.

- Congestion will give problems in evacuation when the occupancy density is higher than 1.5 persons/m^2. CWT is a key part and up to 40% of TET.

In all the scenarios with congestion, there will be two main pinch points for this building:

- The first one is at the door of the lobby of staircase SA.

- The second one is near to the entrance of staircase SB.

More attention should be paid on working out appropriate fire safety management for these pinch points. Fire safety management with a good fire action plan on well-organized evacuation is necessary to ensure safety around the pinch points. Both staircases should be fully utilized in this project. Staircase SB will be more important in evacuation under real scenarios.

ACKNOWLEDGEMENT

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